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Addendum Report

EVALUATION OF REGENERATIVE FUEL CELL

Prepared for

National Aeronautics and Space Administration
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Attn: Mr. Walter Scott

Contract NAS 7-7

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CONTENTS

1. INTRODUCTION

This report gives the results of experimental investigations conducted during a three week extension of Contract NAS 7-7. The object of these investigations was to obtain additional data on the characteristics of the regenerative hydrogen-oxygen fuel cell developed under that contract.

A detailed description of the cell was given in the final report. For the sake of this addendum report a brief description is given below:

Hydrogen electrode - - -	platinized porous nickel
Oxygen electrode - - - -	platinized porous nickel
Electrolyte - - - - -	35 percent KOH solution impregnated in asbestos bed
Cell body - - - - -	stainless steel
Gas seals - - - - -	rubber "O" rings
Gas chambers - - - - -	miniature steel cylinders

The electrodes and electrolyte of the multicell unit were the same as for the single cell unit. The cell spacers consisted of lucite and contained manifolds for conducting the gases from the cylinders to the individual cells and were coated with a layer of nickel to connect the cells in series.

2. ENVIRONMENTAL TESTS

A series of environmental tests was conducted on a single cell at the Jet Propulsion Laboratory, Pasadena, California. The tests, including acceleration, vibration, and shock, were those employed in the Type Approval Tests for the Mariner Spacecraft. The test conditions and cell performance during test are given in the following subsections.

2.1 Static Acceleration

The cell was operated continuously on both charge and discharge for three different types of static acceleration. The charge and discharge current for these and all other environmental tests reported below were respectively 1.0 amp and 0.1 amp. The temperature was 70°F and the gas pressures were near 50 psig.

2.1.1 Test Conditions

The static acceleration test conditions were as follows:

1. 14 g for 5 minutes along the thrust axis in a forward direction.
2. 4 g for 5 minutes along the thrust axis in a reverse direction.
3. 6 g for 5 minutes along the orthogonal axis to "1" and "2" above.

2.1.2 Test Results

The cell voltages during these tests are given as follows. The results indicate that the types of static acceleration have very little if any effect on the electrochemical behavior of this cell.

Test	Process	Time (min)	Voltage (Volts)
a	charge	0	2.18
	"	5	2.18
	discharge	0	0.83
	"	5	0.83
b	charge	0	2.18
	"	5	2.18
	discharge	0	0.83
	"	5	0.83
c	charge	0	2.18
	"	5	2.18
	discharge	0	0.82
	"	5	0.82

2.2 Vibration

The cell was then subjected to two different types of vibration. The test conditions and test results are given below.

2.2.1 Test Conditions

A low and a high frequency test were employed for these tests.

Low Frequency

The low frequency was a sinusoidal vibration at frequencies between 1 and 40 cps for 24 minutes in each of two orthogonal directions. The displacement was $\pm$ 3 inches from 1 to 3 g, peak, from 3 to 40 cps.

High Frequency

The high frequency test consisted of a programmed sequence of band limited white gaussian noise and combined noise and sinusoidal vibration in each of two orthogonal directions. The test lasted 9 minutes in each direction. The frequency range was from 15 to 1500 cps.

2.2.2 Test Results

The cell performance during the low frequency test is as follows:

Position	Process	Time (min)	Voltage (Volts)
Horizontal Axis	charge	0	1.90
	"	24	1.92
	discharge	0	0.85
	"	24	0.88
Thrust Axis	charge	0	1.85
	"	24	1.90
	discharge	0	0.88
	"	24	0.88

The cell performance during the high frequency test is as follows:

Position	Process	Time (min)	Voltage (Volts)
Horizontal Axis	charge	0	1.92
	"	9	1.94
	discharge	0	0.75
	"	9	0.75
Thrust Axis	charge	0	1.82
	"	9	1.86
	discharge	0	0.75
	"	9	0.77

The slight increase in charge voltage with time cannot be attributed to the vibration, as this rise also occurs without vibration. The results indicate very little if any effect of the above types of vibration on electrochemical behavior of the cell.

2.3 Shock

Following the vibration test, the cell was subjected to a shock test. The test conditions and test results are given below.

2.3.1 Test Conditions

The shock test consisted of two (200 g) 0.5 to 1.5 millisecond terminal peak sawtooth shocks in each of two orthogonal directions.

2.3.2 Test Results

The cell performance during the shock tests is given below:

Position	Process	Time	Voltage (Volts)
Horizontal Axis	charge	before	1.82
	"	after	1.82
	discharge	before	0.83
	"	after	0.83
Thrust Axis	charge	before	1.85
	"	after	1.85
	discharge	before	0.83
	"	after	0.83

No effect was observable on an oscilloscope also employed for this test. The results indicate no effect of the above type of shock on the electrochemical behavior of the cell.

3. CYCLING

Automatic cycling was continued on the cell which has been in operation since November 1961. The cell has completed over 1500 shallow cycles of 65 minutes charge and 35 minutes discharge at room temperature.

4. CELL REVERSAL STUDIES

The phenomena of cell reversal was found on several occasions during discharge of the multicell unit. At these times the voltage of one of the nine cells was found to drop suddenly to zero and then become negative (0.2 to 0.8 volts).

This phenomena was explained on the basis of a faulty cell which cannot maintain a voltage as high as the others and is subsequently given a negative charge by them. In order to establish the causes for a cell becoming faulty and reversing while on discharge, a series of experiments was carried out as described below.

4.1 Electrode Activity

The unit was assembled with six cells, five of which contained identical electrodes prepared in the usual manner with 40 mg platinum black per square inch. The electrodes of the sixth cell, however, were unplatinized (untreated porous nickel).

On discharge of the unit the voltages of the five identical cells were all positive and nearly equal, while the voltage of the sixth cell was negative.

This test indicates that one of the causes for reversal is an inactive set of electrodes. Special care should, therefore, be taken to insure that the activity of all sets of electrodes is the same before they are inserted in a unit. The activity test would consist of measurement of the V/I characteristics of the cell with the given electrodes.

4.2 Gas Starvation

Six cells were again employed in a similar test. In this case the electrodes of all six cells were identical; however, the gas inlet manifolds of one cell were partially restricted by the application of a cement. As before, on discharge the voltages of the five identical cells were all positive while the voltage of the sixth cell with restricted gas manifolds was negative.

This test indicates that another cause for cell reversal is an inadequate gas supply to the electrodes. Special care should, therefore, be taken to insure that the gas inlet manifolds are unrestricted before assembling the cell and do not become restricted during operation.

4.3 Electrode Contacts

A third and final experiment consisted of assembling the six cells, all of which were identical except for the fact that one contained a high resistance contact between the electrodes and the nickel plating on a cell spacer. The high resistance was introduced by stripping a large portion of the plating from the area of the spacer behind the electrodes. Again during discharge the voltage of the cell with high contact resistance was negative while the voltages of the others were positive.

This experiment indicates that another cause for cell reversal is a high resistance contact between the electrodes and the intercell connectors. Special care should, therefore, be taken in the preparation of the spacers to insure that the resistances of their nickel platings are identical and low.